



Radioactivity in waters of Mt. Etna (Italy)

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ABSTRACT

Radioactivity in underground waters from Mt. Etna was investigated on the basis of 13 samples. The samples were collected from springs, wells and galleries around the volcano. Water from nine out of thirteen intakes is used for consumption. Activity concentration of uranium isotopes ^{234}U , ^{238}U , radium isotopes ^{226}Ra , ^{228}Ra and radon ^{222}Rn were determined with the use different nuclear spectrometry techniques. The measurements of radium and radon activity concentration were performed with the use of a liquid scintillation counter. The determination of uranium isotopes was carried out with the use of alpha spectrometry. All samples show uranium concentration above Minimum Detectable Activity (MDA), with the highest total uranium ($^{234}\text{U} + ^{238}\text{U}$) activity concentration equal to 130 mBq/l. For radium isotopes, all samples except one showed the activity concentration below MDA. Radon activity concentration was within the range from 1 to 13 Bq/l, hence these waters can be classified as low-radon waters.

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1. Introduction

Long-lived uranium ($T_{1/2} (^{234}\text{U}) = 2.5 \times 10^5$ years, $T_{1/2} (^{238}\text{U}) = 4.7 \times 10^9$ years) and radium ($T_{1/2} (^{226}\text{Ra}) = 1620$ years, $T_{1/2} (^{228}\text{Ra}) = 5.75$ years) isotopes are mainly responsible for the radioactivity content in natural waters. These isotopes during their disintegration from create a series of α - and β -radioactive daughters. After a certain time all isotopes from one radioactive decay series exhibit in secular equilibrium and the isotopic ratio is equal to 1.

Up till now, no data on natural radioactivity in waters in Mt. Etna is available. Ground waters of Mt. Etna's reservoirs were only studied for radon concentration (D'Alessandro and Vita, 2003). The authors measured radon activity concentration in 119 samples around the volcano with the use of a portable Lucas-type scintillation chamber. They obtained results within the range from 1.8 Bq/l to 52.7 Bq/l. The higher values were found in wells, whereas the lower ones in springs and galleries. Moreover, the higher levels of radon concentration were also observed in the eastern sector of the

volcano and lower in the south-western sector. It should be mentioned that all waters can be classified as low-radon waters.

The aim of the present work was to determine the activity concentration of uranium isotopes ^{234}U , ^{238}U and radium isotopes ^{226}Ra , ^{228}Ra in collected underground waters of Mt. Etna's aquifers. Additionally, radon ^{222}Rn concentration level was also examined. Assuming 2 l of water consumption per day (730 l/year) the effective doses for inhabitants resulting from the investigated consumption of radionuclides were calculated.

1.1. Sampling

The authors collected 13 samples from different places around the volcano, from wells, springs, and galleries. Fig. 1 presents the investigated area and the sampling sites. Seven samples were taken from wells, three from springs and three from galleries. Table 1 presents description of the intakes and physical-chemical properties of the investigated waters, i.e. total dissolved solids (TDS), pH, conductivity and temperature.

For radium and uranium determination the samples were collected in 3 l and 0.5 l volume polyethylene bottles, respectively. Samples were acidified to prevent the precipitation of iron as ferric hydroxide in the collecting containers. The initial chemical treatment for radium isotopes was performed at the Università di

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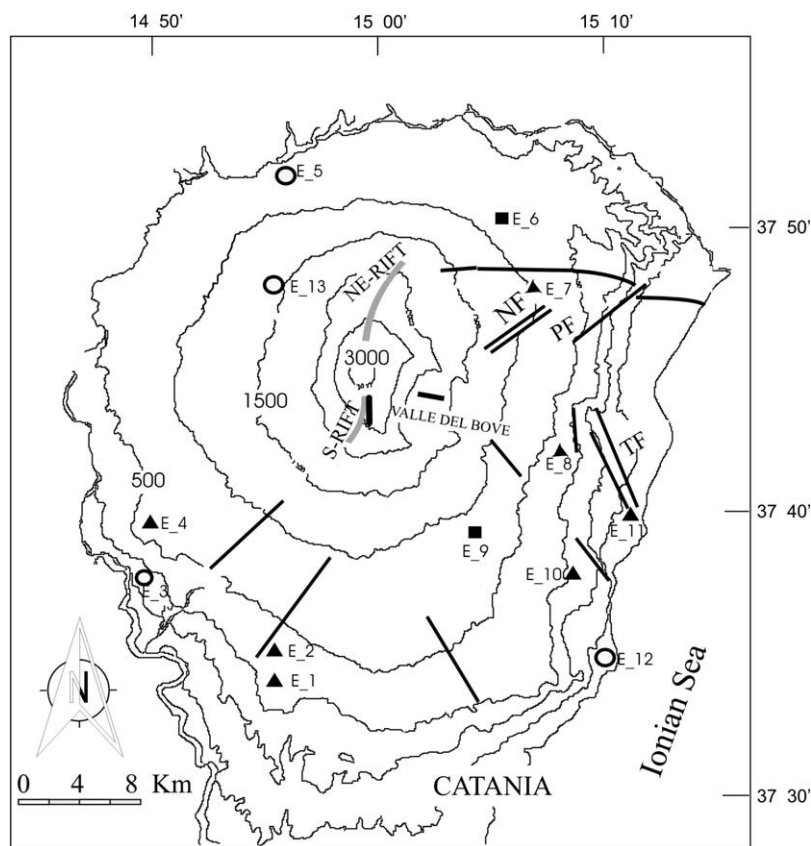


Fig. 1. Study area and sampling sites. The Pernicana Faults (PNF); Naca Faults (NF) and Timpe Fault Systems (TFS) are indicated. The triangles represent the wells, squares the galleries and open circles the springs.

Catania in Dipartimento di Fisica e Astronomia in Catania. Further treatment of the samples for radium and uranium determination was performed at the Department of Nuclear Physics and Its Application, Institute of Physics, University of Silesia in Poland.

For radon determination, samples of the volume of 10 ml were collected by disposable syringes directly at the intakes and immediately put into scintillation vials under 10 ml of scintillation cocktail (Suomela, 1993a). The measurements were performed at the Università di Catania in Dipartimento di Fisica e Astronomia in Catania.

The uncertainties of individual results were calculated as a square root of the sum of uncertainties in all quantities in quadrature.

1.2. Hydrogeology and hydrochemistry of the area

Mt. Etna volcano reaching the altitude of about 3320 m a.s.l., with a diameter of about 40 km, is a typical strato-volcano located in Eastern Sicily. Over the last 500 years Etna has been almost continuously active and has erupted volcanic products essentially consisting of lavas, with a composition ranging from alkali-basalt to hawaiite (Chester et al., 1985). The volcano built up its edifice over a sedimentary substratum that has an estimated thickness of over 15 km (Cristofolini et al., 1979). This basement is mostly composed of clays (Messinian age) to the East and South and of clay, marl and quartz-arenite units, dating from Triassic to upper Pliocene, to the West and North.

Many different lithological types present in the Etna area show remarkable differences in their permeability. Etna's volcanics, in fact, have generally a high permeability (2.5×10^{-7} – 2.9×10^{-6} cm²)

(Aureli, 1973; Ferrara, 1975) whereas the permeability of the sediments of Etna's basement is much lower, with an average value of 10^{-10} cm² (Schilirò, 1988). Such a large permeability contrast together with the remarkable amount of water and snow precipitations that characterize the area, imply that Mt. Etna volcano is also an important reservoir of ground water (about 0.7 km³ of water available per year (Ogniben, 1966)). A considerable part of this volume of water is currently used for drinking purposes by the local population.

The circulation of ground waters inside Mt. Etna is strongly influenced by the morphology of the sedimentary basement of the volcano. In fact, a great majority of water that falls on the ground surface as rain and/or snow percolates through the permeable volcanic rocks. After reaching the impermeable basement, the water flows in radial directions towards the outer boundaries of the volcanic edifice. However, since Etna's basement reaches its maximum height (about 1200 m a.s.l.) slightly NW of the summit of the volcano and has a general slope towards SE, the ground waters tends to flow and accumulate in the Southern and Eastern flanks of the volcanic edifice, where the number of springs and water-wells is actually the greatest (Ogniben, 1966).

Recent hydrogeochemical studies on the Mt. Etna (Aiuppa et al., 2004; Anzà et al., 1989; Dongarrà et al., 1993; Giammanco et al., 1996) showed that its ground waters has a general chemical composition that ranges from bicarbonate alkaline-earth to bicarbonate alkaline. The relative abundance of major elements in solution is generally $(\text{Na}^+, \text{Mg}^{++}) > \text{Ca}^{++} > \text{K}^+$ as regards cations, with magnesium prevailing over sodium in water with higher salinity and bicarbonate (HCO_3^-) always prevailing over other anions. Only very few samples fall into the chloride-sulphate

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